Search for charged Higgs bosons in L3

P. Garcia-Abia

CERN, EP Division, and University of Basel (Switzerland)

Abstract

A search for pair-produced charged Higgs bosons is performed with the L3 detector at LEP using data collected at centre-of-mass energies between 200 and 209 GeV, corresponding to an integrated luminosity of 217.8 pb⁻¹. We observe an excess of events in the H⁺H⁻ \rightarrow cs̄c̄s and cs̄ τ ⁻ $\bar{\nu}_{\tau}$ channels in the mass region around 68 GeV, which is most significant at low values of the H[±] \rightarrow $\tau\nu$ branching ratio. Including data taken at lower centre-of-mass energies, the excess is compatible with a 4.4 σ fluctuation in the background. Interpreting this excess as a statistical fluctuation in the background, lower limits on the charged Higgs mass are derived at the 95% confidence level. They vary from 67.1 to 84.9 GeV as a function of the H[±] \rightarrow $\tau\nu$ branching ratio. These results are PRELIMINARY.

1 Introduction

In the Standard Model [1], the Higgs mechanism [2] requires one doublet of complex scalar fields which leads to the prediction of a single neutral scalar Higgs boson. Extensions to the minimal Standard Model contain more than one Higgs doublet [3]. In particular, models with two complex Higgs doublets predict two charged Higgs bosons.

A search for the process $e^+e^- \to H^+H^-$ is performed in the decay channels $H^+H^- \to \tau^+\nu_\tau\tau^-\bar{\nu}_\tau$, $c\bar{s}\tau^-\bar{\nu}_\tau^{\ 1}$ and $c\bar{s}\bar{c}s$, assumed to be the only possible decays. This allows the interpretation of the results to be independent of the $H^\pm \to \tau\nu$ branching ratio.

2 Data Analysis

The search for pair-produced charged Higgs bosons is performed using the data collected in 2000 with the L3 detector [4] at LEP, corresponding to an integrated luminosity of 217.8 pb⁻¹ collected at an average centre-of-mass energy of 205.9 GeV.

¹The charge conjugate reaction is implied throughout this letter.

The signature for the leptonic decay channel, $H^+H^- \to \tau^+\nu_\tau\tau^-\bar{\nu}_\tau$, is a pair of tau leptons with large missing energy and momentum, giving rise to low multiplicity events with low visible energy and a flat distribution in acollinearity. Almost all the background comes from W-pair production. The number of events expected for a 70 GeV Higgs signal is 17.9 for $Br(H^\pm \to \tau\nu) = 1$.

The semileptonic final state $H^+H^- \to c\bar{s}\tau^-\bar{\nu}_{\tau}$ is characterised by two hadronic jets, a tau lepton and missing momentum. The background is dominated by the process $W^+W^- \to q\bar{q}'\tau\nu$. The number of events expected for a 70 GeV Higgs signal is 12.6 for $Br(H^\pm \to \tau\nu) = 0.5$. Figure 1a displays the distribution of the average of the jet-jet and τ - ν masses. They are calculated from a kinematic fit imposing energy and momentum conservation for an assumed production of equal mass particles, keeping the directions of the jets, the tau and the missing momentum vector at their measured values.

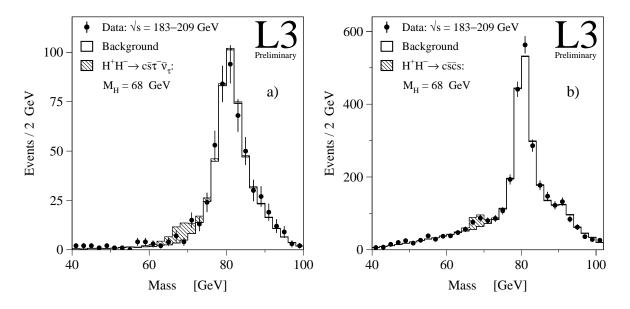


Figure 1: Reconstructed mass spectra in the a) $H^+H^- \to c\bar{s}\tau^-\bar{\nu}_{\tau}$ and b) $c\bar{s}\bar{c}s$ channels, for data and for the expected background. The hatched histogram indicates the expected distribution for a 68 GeV Higgs with a) $Br(H^{\pm} \to \tau \nu) = 0.5$ and b) 0.

Events from the $H^+H^- \to c\bar{s}\bar{c}s$ channel have a high multiplicity and are balanced in transverse and longitudinal momenta. A large fraction of the centre-of-mass energy is deposited in the detector, typically as four hadronic jets. The main contribution to the background comes from W-pair decays into four jets. The number of events expected for a 70 GeV Higgs signal is 35.1 for $Br(H^\pm \to \tau \nu) = 0$. Figure 1b shows the dijet mass distribution after a kinematic fit imposing four-momentum conservation and equal dijet masses. An excess is observed around 68 GeV.

3 Results

The number of selected events in each decay channel is consistent with the number of events expected from Standard Model processes. However, there is an excess of events in the $c\bar{s}\bar{c}s$ and $c\bar{s}\tau^-\bar{\nu}_{\tau}$ mass distributions around 68 GeV. Figure 2a displays the

combined background-subtracted mass distribution for these two Higgs decay channels, where the events are corrected for the efficiency of their respective analyses. The figure also shows the expected distribution for a 68 GeV Higgs with $Br(H^{\pm} \to \tau \nu) = 0.1$. This value of the $Br(H^{\pm} \to \tau \nu)$ is in the range of branching fractions for which the observed excess of events is closest to the expected number for a 68 GeV mass Higgs.

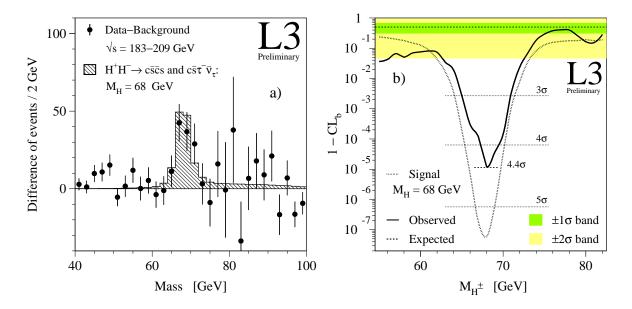


Figure 2: a) Combined background-subtracted mass distribution for the $H^+H^- \to c\bar{s}\bar{c}s$ and $c\bar{s}\tau^-\bar{\nu}_{\tau}$ decay channels. The expected distribution for a 68 GeV Higgs with $Br(H^\pm \to \tau \nu) = 0.1$ is shown by the hatched histogram. b) the background confidence level, $1 - CL_B$, as a function of the Higgs mass with $Br(H^\pm \to \tau \nu) = 0.1$. The solid line shows the values computed from the observed results and the dashed line the expectation for the background only hypothesis. The dotted line is the curve expected for a 68 GeV Higgs signal at this value of the branching ratio. The shaded areas represent the symmetric 1σ and 2σ probability bands expected in the absence of a signal.

A technique based on the log-likelihood ratio [5], $-2\ln(Q)$, is used to calculate a confidence level (CL) that the observed events are consistent with background expectations. For the $c\bar{s}c\bar{s}$ and $c\bar{s}\tau^-\bar{\nu}_{\tau}$ channels, the reconstructed mass distributions (Figures 1a and 1b) are used in the calculation, whereas for the $\tau^+\nu_{\tau}\tau^-\bar{\nu}_{\tau}$ channel, the total number of data, expected background and expected signal events are used. The systematic uncertainties on the background and signal efficiencies, 5% and 2% respectively, are included in the confidence level calculation.

The excess of events around $m_{H^\pm}=68$ GeV is compatible with a 4.4σ fluctuation in the background. The statistical significance of the excess is almost constant for values of $Br(H^\pm\to\tau\nu)$ between 0.1 and 0.2. The data are 1σ below what is expected for a Higgs signal at this mass. Again, this difference is not strongly dependent on the value of the branching fraction. The background confidence level $(1-CL_B)$ is displayed in Figure 2b for the data, for the expectation in the absence of a signal and for a 68 GeV mass Higgs signal. Further investigations of the reported excess are being performed. Interpreting this excess as a statistical fluctuation in the background, lower limits on the charged Higgs mass as a function of the $Br(H^\pm\to\tau\nu)$ are derived [5, 6] at the

$\boxed{ Br(H^{\pm} \to \tau \nu) }$	Lower limits at 95% CL (GeV)	
	observed	median expected
0.0	77.2	77.1
0.1	67.1	76.2
0.5	70.4	75.6
1.0	84.9	83.0

Table 1: Observed and median expected lower limits at 95% CL for different values of the $H^{\pm} \to \tau \nu$ branching ratio. The minimum observed limit, independent of the branching fraction, is at $Br(H^{\pm} \to \tau \nu) = 0.1$.

95% CL, using the data from \sqrt{s} between 199.6 and 209 GeV, as well as those from lower centre-of-mass energies [7].

Table 1 gives the observed and the median expected lower limits for several values of the branching ratio. The region around $m_{H^{\pm}} = 68$ GeV at low values of the $Br(H^{\pm} \to \tau \nu)$ can only be excluded at 78% CL, due to the aforementioned excess of events in this mass region. A similar but less significant excess was observed in our previous publication [7].

Our sensitivity to larger Higgs masses, as quantified by the median expected mass limits given in Table 1, is significantly improved as compared with our previous results at lower centre-of-mass energies [7]. Combining all our data, we obtain a new lower limit at 95% CL of $m_{H^\pm} > 67.1$ GeV, independent of the branching ratio. These results are PRELIMINARY.

References

- S.L. Glashow, Nucl. Phys. 22 (1961) 579; S. Weinberg, Phys. Rev. Lett. 19 (1967) 1264; A. Salam, *Elementary Particle Theory*, edited by N. Svartholm (Almqvist and Wiksell, Stockholm, 1968), p. 367.
- [2] P.W. Higgs, Phys. Lett. 12 (1964) 132, Phys. Rev. Lett. 13 (1964) 508 and Phys. Rev. 145 (1966) 1156; F. Englert and R. Brout, Phys. Rev. Lett. 13 (1964) 321;
 G.S. Guralnik, C.R. Hagen and T.W.B. Kibble, Phys. Rev. Lett. 13 (1964) 585.
- [3] S. Dawson et al., The Physics of the Higgs Bosons: Higgs Hunter's Guide, Addison Wesley, Menlo Park, 1989.
- [4] L3 Collab., B. Adeva et~al., Nucl. Instr. Meth. A 289 (1990) 35.
- [5] ALEPH, DELPHI, L3 and OPAL Collab., The LEP Working Group for Higgs Boson Searches, Preprint CERN-EP/2000-055.
- [6] L3 Collab., O. Adriani et al., Phys. Lett. B 411 (1997) 373.
- [7] L3 Collab., M. Acciarri et al., Phys. Lett. B 496 (2000) 34; L3 Collab., M. Acciarri et al., Phys. Lett. B 466 (1999) 71; L3 Collab., M. Acciarri et al., Phys. Lett. B 446 (1999) 368.